Claims

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1. A method of encoding an digital image comprising a plurality of pixels, said image being able to be transformed by a discrete wavelet transform (DWT) to a predetermined level of decomposition, and capable of being encoded on a block by block basis, each block having a specified block size in number of coefficients, in a first and second dimension, the method comprising the steps of:

a) dividing the image into a plurality of tiles, each tile having firstly, substantially a minimum number of pixels required to produce the number of coefficients in the first dimension of said block at said predetermined level of DWT decomposition, and secondly, less than a minimum number of pixels required to produce the number of coefficients in the second dimension of said block at said predetermined level of DWT decomposition;

b) selecting a current tile;

c) decomposing said current tile using the DWT to at least one level of decomposition to form a plurality of subbands including a LL, LH, HL and HH subband;

d) accumulating coefficients in each subband of the LH, HL and HH subbands to form blocks of said specified size, and encoding each said block to a bit stream;

e) accumulating LL subband coefficients and repeating steps b) to e) until a predetermined number of coefficients of the LL subband have been accumulated;

f) assigning as a current tile said predetermined number of accumulated LL sub-band coefficients;

g) repeating steps c) to g) until the predetermined level of decomposition is reached; and

h) encoding the LL subband into the bit stream.

2. A method according to claim 1, wherein accumulating coefficients in each subband includes accumulating coefficients in corresponding subbands of different tiles.

3. A method according to claim 1, wherein encoding comprises encoding each block substantially as each block is accumulated.

4. A method according to claim 1, wherein said specifying a block size comprises H coefficients in said first dimension by W coefficients in said second dimension.

5. A method according to claim 4, wherein the number of coefficients in the first dimension is equal to the number of coefficients on the second dimension (W=H)

6. A method according to claim 4, wherein said predetermined level is J and the minimum number of pixels in a first dimension of each tile is defined by $2^J H + O(2^J - 1)$ where O is an overlap required by the DWT filter.

7. A method according to claim 6, wherein the number of pixels in a second dimension of each tile is less than that of the first dimension and is defined by $2W$+ O.

8. A method according to claim 1, wherein said DWT filter is a Daubechies 9/7 filter and the overlap required is 7 pixels or coefficients (O=7).

9. A method according to claim 1, wherein said DWT filter is a Haar filter and the overlap required is no pixels or coefficients (O=0).

10. A method of encoding an digital image comprising a plurality of pixels, said image being able to be transformed by a discrete wavelet transform (DWT) to a

predetermined level of decomposition and capable of being encoded on a block by block basis, each block having a specified block size in number of coefficients, in a first and second dimension, the method comprising the steps of:

a) dividing the image into a plurality of tiles, each tile having firstly, substantially a minimum number of pixels required to produce the number of coefficients in the first dimension of said block at said predetermined level of DWT decomposition, and secondly, less than a minimum number of pixels required to produce the number of coefficients in the second dimension of said block at said predetermined level of DWT decomposition;

b) selecting a tile of the image as a current tile;

c) decomposing said current tile using the DWT to a provide a plurality of coefficients in LL, LH, HL and HH subbands;

d) encoding coefficients of the LH, HL, HH subbands of a current level into a bit-stream;

e) determining if said current level is the predetermined level:

ea) encoding the coefficients of the LL subband into the bitstream, if the current level is the predetermined level; and repeating steps b) to e); and

eb) storing coefficients not previously encoded of the LL subband if the current level is not the predetermined level;

f) determining if the number of said stored coefficients of the LL subband at the current level is at least a predetermined number:

fa) assigning said predetermined number of LL coefficients as a current tile, if the number of stored LL coefficients is at least said predetermined number; and repeating steps c) to f); and

fb) repeating steps b) to f) if the number of stored LL coefficients is less than said predetermined number.

11. A method according to claim 10, wherein said specified block size comprises H coefficients in said first dimension by W coefficients in said second dimension.

12. A method according to claim 11, wherein the number of coefficients in the first dimension is equal to the number of coefficients on the second dimension of said specified block (W=H)

13. A method according to claim 11, wherein said predetermined level is J and the minimum number of pixels in a first dimension of each tile is defined by, where O is an overlap required by the DWT filter.

14. A method according to claim 13, wherein the number of pixels in a second dimension of each tile is less than that of the first dimension and is defined by $2W+O$.

15. A method according to claim 10, wherein said DWT filter is a Daubechies 9/7 filter and the overlap required is 7 pixels or coefficients (O=7).

16. A method according to claim 10, wherein said DWT filter is a Haar filter and the overlap required is no pixels or coefficients (O=0).

17. A method according to claim 10, wherein said encoding is preformed by a bit-plane entropy encoder.

18. A method according to claim 10, wherein said encoding is preformed by an Arithmetic Encoder.

19. A method according to claim 10, wherein said encoding is preformed by a hybrid encoder comprising an Arithmetic and Bit-plane entropy Encoder.

20. An apparatus for encoding an image, said image being capable of being transformed by a discrete wavelet transform (DWT) to a predetermined level of decomposition and capable of being encoded on a block by block basis, each block having a specified block size in number of coefficients, in a first and second dimension, the apparatus comprising:

a) means for dividing the image into a plurality of tiles, each tile having firstly, substantially a minimum number of pixels required to produce the number of coefficients in the first dimension of said block at said predetermined level of DWT decomposition, and secondly, less than a minimum number of pixels required to produce the number of coefficients in the second dimension of said block at said predetermined level of DWT decomposition;

b) selecting means for selecting a current tile;

c) decomposing means for decomposing said current tile using the DWT to at least one level of decomposition to form a plurality of subbands including a LL, LH, HL and HH subband;

d) means for accumulating a predetermined number of coefficients of the LL sub-band coefficients;

e) means for assigning, as a current tile, said predetermined number of accumulated LL subband coefficients;

f) means for feeding back the current tile to the decomposing means for decomposing the current tile to a further level of decomposition;

g) means for accumulating coefficients in each subband of the LH, HL and HH subbands to form blocks of said specified size, and accumulating at least one block of said specified size in the LL subband at said predetermined level; and

h) encoding means for encoding each said block to a bit stream.

21. An apparatus for encoding an image, said image being capable of being transformed by a discrete wavelet transform (DWT) to a predetermined level of decomposition, and capable of being encoded on a block by block basis, each block having a specified block size in number of coefficients, in a first and second dimension, the apparatus comprising:

storage means for storing at least a portion of said image, the portion of the image having firstly, substantially a minimum number of pixels required to produce the number of coefficients in the first dimension of said block at said predetermined level of DWT decomposition, and secondly, less than a minimum number of pixels required to produce the number of coefficients in the second dimension of said block at said predetermined level of DWT decomposition;

a first and second filtering means for applying a linear transform to a first and second dimension of said image portion respectively to provided a LL, LH, HL and HH subband, each subband comprising at least one coefficient;

a partial band storage means for accumulating a predetermined number of coefficients of the LL subband, and using the accumulated LL coefficient as an image portion for refiltering by the first and second filtering means to achieve a next level decomposition;

a subband storage means for accumulating said blocks of specified size for each level in the LH, HL and HH subbands, and accumulating said blocks of specified size in the LL subband at said predetermined level of decomposition; and

encoder means for encoding each accumulated block into a bit stream.

22. An apparatus according to claim 20, wherein said encoder means is a bit-plane entropy encoder.

23. An apparatus according to claim 21, wherein said encoder means is a bit-plane entropy encoder.

24. An apparatus according to claim 20, wherein said encoder means is an Arithmetic Encoder.

25. An apparatus according to claim 21, wherein said encoder means is an Arithmetic Encoder.

26. An apparatus according to claim 20, wherein said encoder means is a hybrid encoder comprising an Arithmetic Encoder and Bit-plane entropy Encoder.

27. An apparatus according to claim 21, wherein said encoder means is a hybrid encoder comprising an Arithmetic Encoder and Bit-plane entropy Encoder.

28. A computer readable memory medium for storing a program for apparatus which encodes an digital image comprising a plurality of pixels, said image being able to be transformed by a discrete wavelet transform (DWT) to a predetermined level of decomposition and capable of being encoded on a block by block basis, each block having a specified block size in number of coefficients, in a first and second dimension, said program comprising:

a) code for a dividing step for dividing the image into a plurality of tiles, each tile having firstly, substantially a minimum number of pixels required to produce the number of coefficients in the first dimension of said block at said predetermined level of DWT decomposition, and secondly, less than a minimum number of pixels required to produce the number of coefficients in the second dimension of said block at said predetermined level of DWT decomposition;

b) code for a selecting step for selecting a current tile;

c) code for a decomposing step for decomposing said current tile using the DWT to at least one level of decomposition to form a plurality of subbands including an LL, LH, HL and HH subband;

d) code for an accumulating step for accumulating coefficients in each subband of the LH, HL and HH subbands to form blocks of said specified size and for encoding each said block to a bit stream;

e) code for an accumulating step for accumulating LL subband coefficients, and for repeating steps b) to e) until a predetermined number of coefficients of the LL subband have been accumulated;

f) code for an assigning step for assigning as a current tile said predetermined number of accumulated LL subband coefficients;

g) code for repeating steps c) to g) until the predetermined level of decomposition is reached; and

h) code for an encoding step for encoding the LL subband into the bit stream.

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29. A computer readable memory medium according to claim 28, wherein said code for accumulating coefficients in each subband is adapted to include steps for accumulating coefficients in corresponding subbands of different tiles.

30. A computer readable memory medium according to claim 28, wherein said code for encoding is adapted to include steps for encoding each block substantially as each block is accumulated.

31. A computer readable memory medium according to claim 28, wherein said code for specifying a block size is adapted to include steps for specifying H coefficients in said first dimension by W coefficients in said second dimension.

32. A computer readable memory medium according to claim 31, said code being adapted so that the number of coefficients in the first dimension is equal to the number of coefficients on the second dimension (W=H)

33. A computer readable memory medium according to claim 31, said code being adapted so that said predetermined level is J and the minimum number of pixels in a first dimension of each tile is defined by where O is an overlap required by the DWT filter.

34. A computer readable memory medium according to claim 33, said code being adapted so that the number of pixels in a second dimension of each tile is less than that of the first dimension and is defined by $2W+$ O.

35. A computer readable memory medium according to claim 28, said code being adapted so that said DWT filter is a Daubechies 9/7 filter and the overlap required is 7 pixels or coefficients (O=7).

36. A computer readable memory medium according to claim 28, said code being adapted so that said DWT filter is a Haar filter and the overlap required is no pixels or coefficients (O=0).

37. A computer readable memory medium for storing a program for apparatus which encodes an digital image comprising a plurality of pixels, said image being able to be transformed by a discrete wavelet transform (DWT) to a predetermined level of decomposition and capable of being encoded on a block by block basis, each block having a specified block size in number of coefficients, in a first and second dimension, said program comprising:

a) code for a dividing step for dividing the image into a plurality of tiles, each tile having firstly, substantially a minimum number of pixels required to

produce the number of coefficients in the first dimension of said block at said predetermined level of DWT decomposition, and secondly, less than a minimum number of pixels required to produce the number of coefficients in the second dimension of said block at said predetermined level of DWT decomposition;

b) code for a selecting step for selecting a tile of the image as a current tile;

c) code for a decomposing step for decomposing said current tile using the DWT filter to provide a plurality of coefficients in LL, LH, HL and HH subbands;

d) code for an encoding step for encoding coefficients of the LH, HL, HH subbands of a current level into a bitstream;

e) code for a determining step for determining if said current level is the predetermined level:

ea) code for an encoding step for encoding the coefficients of the LL subband into the bitstream, if the current level is the predetermined level; and repeating steps b) to e); and

eb) code for a storing step for storing coefficients not previously encoded of the LL subband if the current level is not the predetermined level;

f) code for a determining step for determining if the number of said stored coefficients of the LL subband at the current level is at least a predetermined number:

fa) code for an assigning step for assigning said predetermined number of LL coefficients as a current tile, if the number of stored LL coefficients is at least said predetermined number, and repeating steps c) to f); and

fb) code for a repeating step for repeating steps b) to f) if the number of stored LL coefficients is less than said predetermined number.

38. A computer readable memory medium according to claim 37, said code being adapted so that specified block size comprises H coefficients in said first dimension by W coefficients in said second dimension.

39. A computer readable memory medium according to claim 38, said code being adapted so that the number of coefficients in the first dimension is equal to the number of coefficients on the second dimension of said specified block (W=H)

40. A computer readable memory medium according to claim 38, said code being adapted so that said predetermined level is J and the minimum number of pixels in a first dimension of each tile is defined by, where O is an overlap required by the DWT filter.

41. A computer readable memory medium according to claim 40, said code being adapted so that the number of pixels in a second dimen-sion of each tile is less than that of the first dimension and is defined by $2W-$ O.

42. A computer readable memory medium according to claim 37, said code being adapted so that said DWT filter is a Daubechies 9/7 filter and the overlap required is 7 pixels or coefficients (O=7).

43. A computer readable memory medium according to claim 37, said code being adapted so that said DWT filter is a Haar filter and the overlap required is no pixels or coefficients (O=0).

44. A computer readable memory medium according to claim 37, wherein said steps for encoding are adapted to perform encoding in accordance with a bit-plane entropy encoding process.

45. A computer readable memory medium according to claim 37, wherein said steps for encoding are adapted to perform encoding in accordance with an Arithmetic Encoding process.

46. A computer readable memory medium according to claim 37, wherein said steps for encoding are adapted to performed encoding in accordance with a hybrid encoding process comprising Arithmetic and Bit-plane entropy encoding sub-processes.

47. A method of encoding an digital image comprising a plurality of pixels, said image being able to be transformed by a discrete wavelet transform (DWT) to a predetermined number of levels of decomposition being at least two levels, and further capable of being encoded on a block by block basis, each block having a specified block size in number of coefficients, in a first and second dimension, the method comprising the steps of:

a) dividing the image into a plurality of tiles, each tile having firstly, substantially a minimum number of pixels required to produce the number of coefficients in the first dimension of said block at said predetermined level of DWT decomposition, and secondly, less than a minimum number of pixels required to produce the number of coefficients in the second dimension of said block at said predetermined level of DWT decomposition;

b) selecting a current tile;

c) decomposing said current tile using the DWT to at least one level of decomposition to form a plurality of subbands including LL, LH, HL and HH subbands;

d) accumulating coefficients in each subband of the LH, HL and HH subbands to form blocks of said specified size and encoding each said block to a bit stream;

e) accumulating LL subband coefficients and repeating steps b) to e) until a predetermined number of coefficients of the LL subband have been accumulated;

f) assigning as a current tile said predetermined number of accumulated LL sub-band coefficients;

g) repeating steps c) to g) until the predetermined level of decomposition is reached; and

h) encoding the LL subband into the bit stream.

48. A method of encoding a digital image comprising the steps of:

a) dividing the image into a plurality of tiles to decompose each tile to form a plurality of subbands including a LL, LH, HL and HH subband by using a discrete wavelet transform (DWT);

b) selecting a current tile;

c) decomposing said current tile to form a plurality of subbands including a LL, LH, HL and HH subband by using the DWT;

d) encoding LH. HL and HH subbands;

e) accumulating LL subband coefficients and repeating steps b) to e) until a predetermined number of coefficients of the LL subband have been accumulated;

f) assigning, as a current tile, said predetermined number of accumulated LL subband coefficients;

g) repeating steps c) to g) until the predetermined level of decomposition is reached; and

h) encoding the LL subband.

49. An apparatus for encoding a digital image comprising:

a) means for dividing the image into a plurality of tiles to decompose each tile to form a plurality of subbands including a LL, LH, HL and HH subband by using a discrete wavelet transform (DWT);

b) selecting means for selecting a current tile;

c) decomposing means for decomposing said current tile to form a plurality of subbands including a LL, LH, HL and HH subband by using the DWT;

d) encoding means for encoding LH, HL and HH subbands;

e) means for accumulating LL subbands;

f) means for assigning, as a current tile, said predetermined number of accumulated LL subband coefficients; and

g) encoding means for encoding the LL subband.

50. A method of decoding a digital image comprising a plurality of pixels, said image having been transformed by a discrete wavelet transform (DWT) to a predetermined level of decomposition, and having been encoded on a block by block basis, each block having a specified block size in number of coefficients, in a first and second dimension, the image having been divided into a plurality of tiles, each tile having firstly, substantially a minimum number of pixels required to produce the number of coefficients in the first dimension of said block at said predetermined level of DWT decomposition, and secondly, less than a minimum number of pixels required to produce the number of coefficients in the second dimension of said block at said predetermined level of DWT decomposition, the decoding method comprising substantially the inverse steps to those recited in claim 1.

51. An apparatus adapted for decoding a digital image comprising a plurality of pixels, said image having been transformed by a discrete wavelet transform (DWT) to a predetermined level of decomposition, and having been encoded on a block by block basis, each block having a specified block size in number of coefficients, in a first and

second dimension, the image having been divided into a plurality of tiles, each tile having firstly, substantially a minimum number of pixels required to produce the number of coefficients in the first dimension of said block at said predetermined level of DWT decomposition, and secondly, less than a minimum number of pixels required to produce the number of coefficients in the second dimension of said block at said predetermined level of DWT decomposition, said apparatus adapted to implement the method recited in claim 50.